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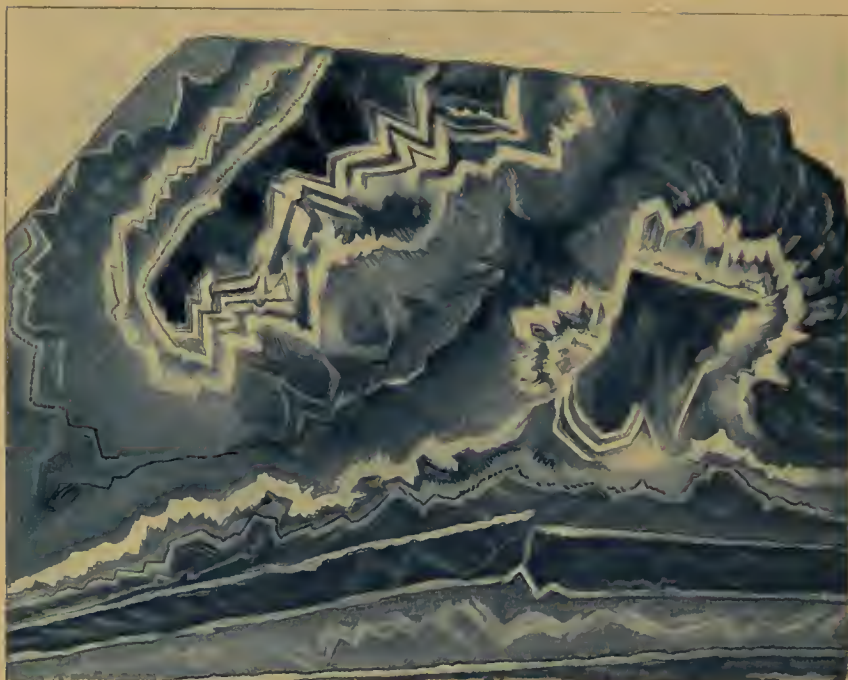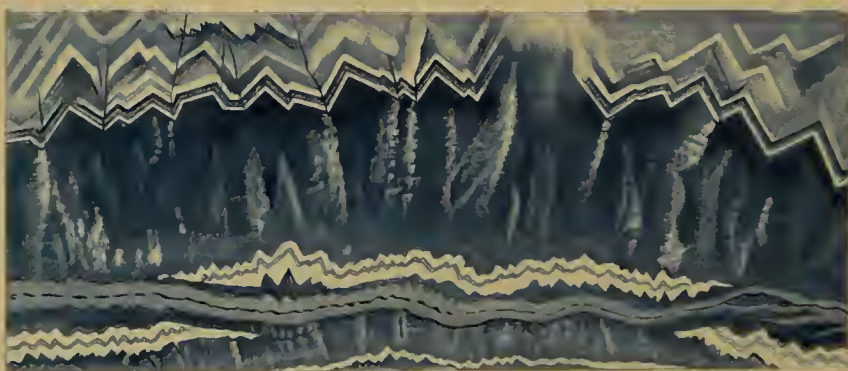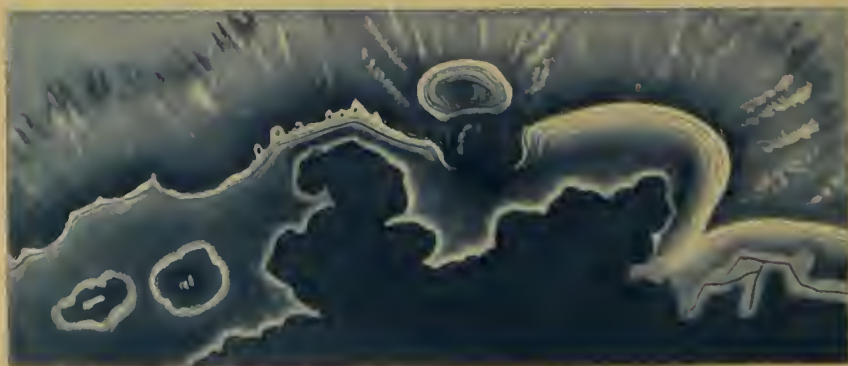
Fig. 1.

Fig 2.

R. xn del.　　　　　　　Fig. 3.

AMETHYST-QUARTZ

with warped Faults in concretion

ON BRECCIATED CONCRETIONS.

By John Ruskin, Esq., F.G.S.

(PLATE III.)

THE states of semi-crystalline silica are so various, and so con-
nected in their variety, that the best recent authorities have
been content to group them all with quartz, giving to each only a
few words of special notice ; even the important chapters of Bischof
describe rather their states of decomposition and transition than the
minerals themselves.   Nevertheless, as central types, five conditions
of silica are definable, structurally, if not chemically, distinct ; and
forming true species : and in entering on any detailed examination
of agatescent arrangements, it is quite necessary to define with pre-
cision these typical substances, and their relation to crystalline quartz.

I. *Jasper.*—Opaque, with dull earthy fracture ; and hard enough
to take a perfect polish. When the fracture is conchoidal the mineral
is not jasper, but stained flint.   The transitional states are confused
in fracture ; but true jasper is absolutely separated from flint by two
structural characters ; on a small scale it is capable of the most
delicate pisolitic arrangement ; and on a larger scale is continually
found in flame-like concretions, beautifully involved and contorted.
But flint is never pisolitic, and, in any fine manner, never coiled ; nor
do either of these structures take place in any transitional specimen,
until the conchoidal fracture of the flint has given place to the dull
earthy one of jasper ; nor is even jasper itself pisolitic on the fractures
being too close-grained.   The green base of heliotrope, with a per-
fectly even fracture, may be often seen, where it is speckled with
white, to be arranged in exquisitely sharp and minute spherical con-
cretions, cemented by a white paste, of which portions sometimes
take a completely brecciated aspect, each
fragment being outlined by concave seg-
ments of circles (Fig. 1). Jasper is emi-
nently retractile, like the clay in septaria,
and in agates often breaks into warped
fragments, dragging the rest of the stone
into distortion. In general, the imbedded
fragments in any brecciated agate will be

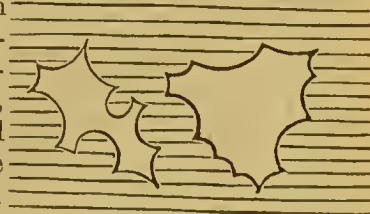Fig. 1.

mainly of jasper ; the cement, chalcedonic, or quartzose.

II. *Flint.*—Amorphous silica, translucent on the edges, with fine
conchoidal fracture.   Opaque only when altered, nascent, or stained.
Never coiled, never pisolitic, never reniform ; these essentially ne-
gative characters belonging to it as being usually formed by a slow
accumulative secretion, and afterwards remaining unmodified (pre-
serving therefore casts of organic forms with great precision).   It is
less retractile than jasper ; its brecciate conditions being not so much
produced by contraction or secession, as by true secretion, even when
most irregular in shape (as a row of flints in chalk differ from the
limestone fragments represented in Vol. IV. Plate XX. Fig. 3, which
might stand for a jasperine structure also).   But there are innumer-

able transitions between these two states, affected also by external violence, which we shall have to examine carefully. Within these nodular concretions, flint is capable of a subsequently banded, though not pisolitic arrangement. (See Dr. S. P. Woodward's paper on banded flints, in this MAGAZINE, Vol. I. for October, 1864, p. 145.)

III. *Chalcedony.*—Reniform silica, translucent when pure, opaque only when stained, nascent, or passing into quartz. The essential characteristic of chalcedony is its reniform structure, which in the pure mineral is as definite as in wavellite or hæmatite, though when it is rapidly cooled or congealed from its nascent state of fluent jelly it may remain as a mere amorphous coating of other substances ; very rarely, however, without some slight evidence of its own reniform crystallization. The study of its different degrees of congelation in agates is of extreme intricacy. As a free mineral in open cavities it is actively stalactitic, not merely pendant or accumulative, but animated by a kind of crystalline spinal energy, which gives to its processes something of the arbitrary arrangement of real crystals, modified always by cohesion, gravity, and (presumably) by fluid and gaseous currents.

There is no transition between chalcedony and flint. They may be intimately mixed at their edges, but the limit is definite. Impure brown and amber-coloured chalcedonies, and those charged with great quantities of foreign matter, may closely resemble flint, but the two substances are entirely distinct. Between jasper and chalcedony the separation is still more definite in mass, jasper being never reniform, and differing greatly in fracture ; but the flame-like or spotted crimson stains of chalcedony often approach conditions of jasper ; and there is, I suppose, no pisolitic formation of any substance without some inherent radiation, which associates it with reniform groups, so that pisolitic jasper must be considered as partly transitive to chalcedony. On the other hand chalcedony seems to pass into common crystalline quartz through milky stellate quartz, associated in Auvergne with guttate and hemispherical forms.

IV. *Opal.*—Amorphous translucent silica, with resinous fracture, and essential water. Distinguished from chalcedony by three great structural characteristics : *a*, its resinous fracture ; *b*, that it is never pisolitic or reniform ; *c*, that when zoned, in cavities or veins, its *zones are always rectilinear*, and transverse to the vein, while those of chalcedony are usually undulating, and parallel to the sides of the vein ; level only in lakes at the bottom of cavities.

Fig. 2.

V. *Hyalite.* — Amorphous transparent silica, with vitreous fracture, and essential water. Never reniform, nor pisolitic, nor banded ; but composed of irregularly grouped bosses, generally elliptical or pear-shaped (only accidentally spherical), formed apparently by successive accretion of coats, but not showing banded structure internally (Fig. 2). Entirely transparent, with splendid smooth glassy fracture. Sometimes coating lava ; sometimes in irregularly isolated patches upon

it: apparently connected in structure with the roseate clusters of milky chalcedony of Auvergne. I shall keep the term "guttate" for this particular structure, of which singular varieties also occur among the hornstones of Cornwall.

These five main groups are thus definable without embarrassment: two other conditions of silica, perhaps, ought to be separately named; namely, cacholong, which seems to take a place between chalcedony and opal, but which I have not yet been able satisfactorily to define; the other, the calcareous-looking, usually whitish agate, which often surrounds true translucent agate, as if derived from it by decomposition. I am under the impression that this is chalcedony, more or less charged with carbonate of lime, and that it might be arranged separately as lime-jasper, differing from aluminous jasper by being capable of reniform structure; but it is certainly in some cases an altered state of chalcedony, which seems in its more opaque zones to get whiter by exposure to light. I shall therefore call it white agate, when it harmoniously follows the translucent zones; reserving the term jasper for granular aggregations. Perhaps ultimately it may be found that nascent chalcedony can take up either oxide of iron, or alumina, or lime, and might relatively be called iron-jasper, clay-jasper, and lime-jasper; but for any present descriptive purpose the simpler arrangement will suffice.

These, then, being the principal types of agatescent silica, it is of importance to define clearly the two structures I have severally called pisolitic and reniform.

A pisolitic mineral is one which has a tendency to separate by spherical fissures, or collect itself by spherical bands, round a central point.

A reniform mineral is one which crystallizes in radiation from a central point, terminating all its crystals by an external spherical surface. It is, however, difficult to define this character mathematically. On the one hand, radiate crystals may be terminated by spherical curves, as in many zeolites, without being close set enough to constitute a reniform mass; on the other, radiate crystals, set close, may be terminated so as to prevent smoothness of external spherical surface, and I am not sure whether this smoothness is a mere character of minute scale (so that chalcedony, seen delicately enough, might present pyramidal extremities of its fibres on the apparently smooth surface), or whether, in true reniform structure, the crystallization is actually arrested by a horizontal plane: I do not mean a cystalline plane, as in beryl, but one of imperfect crystallization, presenting itself only under a peculiar law of increase. Thus, in hæmatite, which is both reniform and pisolitic, the masses often divide in their interior by surfaces of jagged crystallization, while externally they are smooth and even lustrous; but I put this point aside for future enquiry, because it will require us to go into the methods of possible increment in quartz-crystals, and for our present purpose, we need only a clear understanding of two plainly visible conditions of jasper and chalcedony, namely, that jasper will collect itself pisolitically, out of an amorphous mass, into concretion round central points, but not actively terminate its external surface by spherical

curves ; while chalcedony will energetically so terminate itself externally, but will, in ordinary cases, only developo its pisolitic structure subordinately, by forming parallel bands round any rough surface it has to cover, without collecting into spheres, unless either provoked to do so by the introduction of a foreign substance, or encouraged to do so by accidentally favourable conditions of repose. And here branch out for us two questions, both most intricate ; first, as to the introduction of foreign bodies ; secondly, as to the crystalline disposition of chalcedony, under variable permission of repose.

First—As to foreign substances.   I assume that in true pisolitic concretion, such as that of the jasper, roughly sketched in Fig. 3.
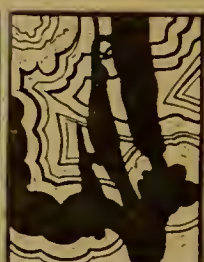

Fig. 3.   Fig. 4.   Fig. 5.

(it is not a coral—the radiant lines are merely conventional indications of the grain of the jasper, so far as it is visible with a lens[1]), no foreign body has provoked the orbicular arrangement. The jasper is red ; the little dark circles are wells of pure chalcedony, each containing within it a white ball of crystallized quartz, forming a star on the section. The whole is magnified about three times in the drawing, being a portion of a horizontal layer, alternating with solid white jasper. It scems that the pisolitic structure is here truly native ; but we must nevertheless grant the possibility that the balls of quartz may have had somo organic atom for their nucleus.   On the other hand, in the ordinary conditions of dendritic agate, in which stalactites of chalcedony surround branches of clearly visible chlorite,[2] or of oxido of iron or manganese, I assume that in the plurality of cases, such sustaining substances have been first developed, and the chalcedonic stalactite afterwards superimposed, being, in the most literal senso of the word, "superfluous" silica ; but I, nevertheless, see great reason for thinking that, in many cases, the core of the group is only a determination to its centre of cloments which had been dispersed through the mass.   In the generality of Mocha-stones, the dendritic oxides, so far from being an original framework, are clearly of subsequent introduction, radically following the course of fissures from which they float partially into tho body of tho imperfectly congealed gelatinous mass ; in other moro raro, and singularly beautiful cases, the metallic oxides ramify in curves in the intervals of tho pisolitic belts, and

[1] In my woodcut diagrams I shall employ no fine execution ; they will be merely illustrative, not imitative,—diagrams, not drawings. In the plates, on the contrary, with Mr. Allen's good help, I shall do the best I can.

[2] Or green earth ?   I cannot find any good account of the green substance which plays so important a part in the exterior coats of agates, and Iceland chalcedonics.

then there is nearly always a dark rod in the stalactitic centre, which may or may not be solid. In the finest Mocha stones, I think it is a black film round a chalcedonic nucleus; but in the associations of limonite with chalcedony, it is usually of solid radiate iron-oxide, and doubtless of prior, though perhaps only of immediately prior, formation. A more complex state is presented by such stalactites, when enveloped in a chalcedonic solid paste, to which they do not communicate their own zoned structure. Ordinarily, the surrounding mass throws itself into zones parallel with those of the enclosed stalactite; but, in some cases, it is of quite adverse structure, perhaps laid level across the stalactitic fall.

The conditions admitting the interfusion of this solid paste, are strangely connected with those which cause chalcedony to form true vertical stalactites and straight rods, instead of arborescent and twisted stalactites. I have never seen the twisted stalactite unless enveloping fibres of some foreign, perhaps organic, substance, enclosed in massive chalcedony; but the straight stalactite is perhaps oftener so than free (unless connected with limonite), and it would appear, therefore, as if the apparently interposed mass were really of contemporary formation, or else it would sometimes enclose the contorted stalactite. But this question respecting the causes of the vertical and twisted groups properly belongs to the second branch of our inquiry as to states of repose.

Second: Conditions affecting mode of crystallization. It is evident that fluent deposits of silica contained in a rock-cavity must be affected, in course of their solidification, not only by every addition to their own mass, but by every change in the temperature or grain of the surrounding rock, so that we have innumerable modifications of state, dependent partly on accession and transmission of substance, partly on changes in external temperature and pressure. And, under these influences, we perceive that the gelatinous silica occasionally obeys gravity,[1] and occasionally resists it, becoming sometimes pendent from the roof, and forming level lakes on the floor of cavities; at other times, throwing parallel bands on floor and roof alike, and in transitional periods, forming thick layers on the floor, and thin ones at the sides, the layers being liable, meantime, to different degrees of compression from their own modes of solidification, which give them, locally, the appearance of an elastic compression and expansion: there seems no limit to the fineness of their lines at these compressed points, when their continuity is uninterrupted. Figures 6 and 7 illustrate, in two small pieces of agate, each here magnified about three times, most of the appearances which must be severally studied. In Fig. 6 the lowest band, A. level at the bottom, broken irregularly towards the rough side of the stone, is yet of nearly even thickness everywhere; above it, the

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[1] I use this word gravity in some doubt; not being quite sure that the straight beds are always horizontal, or always inferior to the rest deposited at the same time. I have one specimen in which, according to all analogies of structure, it would appear that the vacant space is *under* the level floor, between it and reniform chalcedony; and sometimes these floors cross pillars of stalactite like tiers of scaffolding.

one with a black central line encompasses the whole agate symmetrically. Then a white band, thin at the bottom, projects into concretions on the flanks. Then, a thick white deposit, B. does not ascend at the flank at all; then a crystalline bed, with pisolitic concretions at the bottom of it, changes into dark chalcedony (drawn as black), which ascends at the flanks. Then another thin line at the bottom, in concretion at flanks; then one thick at the bottom, thin at the flanks, and so upwards, In Fig. 7, a level mass, itself composed of
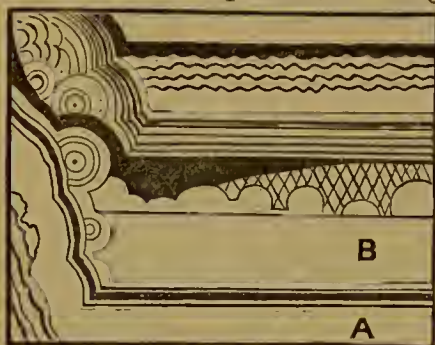

Fig. 6.   Fig. 7.

silica in two different states, one separating into flakes, and the other even-laid, is surrounded by bands which melt into it with gradually diminishing thickness, these being evidently subordinate to an external formation of crystalline quartz; the whole terminated by a series of fine bands of graduated thickness, and by clear chalcedony (drawn as black).

Now all these, and many more such variations, take place without any apparent disturbance of the general mass, each bed conforming itself perfectly to the caprice of its neighbour, and leaving no rents nor flaws. But an entirely different series of phenomena arise out of the fracture or distortion of one deposit by another, after the first has attained consistence. Thus, in Fig. 4, a yellow orbicular jasper is split into segments, singularly stellate, or wheel-like, and then variously lifted and torn by superimposed chalcedony; and in Fig. 5, a white and opaque agatescent mass is rent, while still ductile, the rents being filled with pure chalcedony: and from this state, in which the pieces are hardly separate, and almost hang together by connecting threads, we may pass on through every phase of dislocation to perfect breccia; but, all the while, we shall find the aspect of each formation modified by another kind of fault, which has no violent origin, and for the illustration of which I have prepared Plate III. This plate represents (all the figures being of the natural size) three sections of amethystine agate, in which the principal material is amethyst-quartz, and the white jasperine bands for the most part form between the points of the crystals.

All the three examples are types of pure concrete agatescence in repose, showing no trace whatever of external disturbance. The fault in the inclined bed at the base of the uppermost figure, has some appearance of having been caused by a shock; but for that reason is all the more remarkable, the bed beneath it being wholly

undisturbed, and its own fracture quite structural, and connected with the crystalline elevation and starry concretion above. I have no idea at present why the central portions of these concretions of dark amethyst are partly terminated by right lines, or what determines the greater number of bands on one side than on the other.

The second figure is of a less varied, but of still more curious interest. There is no trace of violence or fracture in the stone, and the line of the crystallized amethystine mass is undisturbed at the summits, except by a partial dissolution in one part and mingling with the white bands above. But the white undulatory band at its base is cut into three parts, and the intermediate portion lifted (or the flanks removed downwards), a quarter of an inch, by pure calm crystalline action, giving thus room for an interferent brown vein of less definite substance which proceeds without interruption, dividing the white band in a direction peculiarly difficult to explain, unless by supposing the interferent one to be the slow filling of a fissure originally opened in the direction of the black line in Fig. 8, and straightened in widening.

Fig. 8.

But the third example is inexplicable, by any such supposition. It is the agatescent centre of a large amethyst nodule, in which a small portion, about the third of an inch long and a quarter of an inch thick, of its encompassing belt, is separated bodily from the rest, taken up into the surrounding concretion of quartz, and its place supplied by a confused segregation of chalcedony, with a sprinkled deposit of jasper spots on the surface exposed by this removal of its protecting coat; spots, which in the rest of the stone, form on the exterior of the coat itself, just under the quartz. There are many points in all these three examples which it is useless to take further note of at present, but to which I shall return, after collecting examples enough to form some basis of reasoning and comparison. I must apologize, as it is, for the length of this paper on a subject partly familiar, partly trivial, yet in which these definitions, not by skill of mine expressible in less room, were necessary before I could proceed intelligibly.